FIELD INVESTIGATIONS OF HRC®-STIMULATED BIOREDUCTION OF Cr(VI) AT HANFORD 100H

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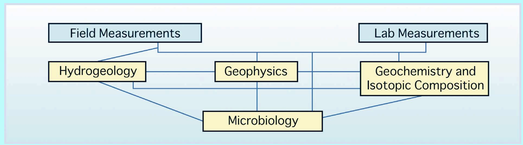
HYPOTHESIS

Lactate (Hydrogen Release Compound, HRC™) injection into chromium-contaminated groundwater through an injection well will cause bioreduction of chromate [Cr (VI)] and precipitation of insoluble species of [Cr(III)] on soil particles, probably catalyzed at oxide surfaces at the field scale.

OBJECTIVE

To perform field investigations to assess the potential for immobilizing and detoxifying chromium contaminated soils and groundwater using bioremediation at Site 100H at Hanford

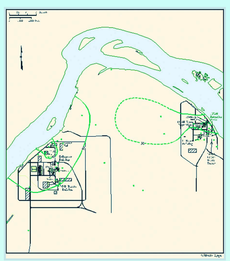
TYPES OF RESEARCH



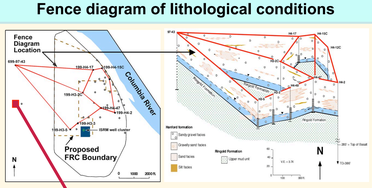
- Drilling, coring, and completion of two new boreholes a field site
- Evaluation and development of a conceptual model of background conditions
- Microbial and lactate-induced treatability studies
- Geophysical characterization and monitoring
- Hydraulic measurements

Hanford 100H Site
Geological, Hydrological, and Geophysical Conditions

Distribution of chromium in groundwater, Hanford100D and 100H areas, 1994

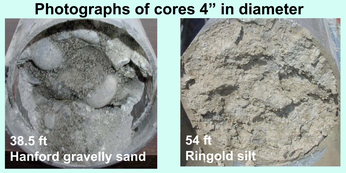


Fence diagram of lithological conditions

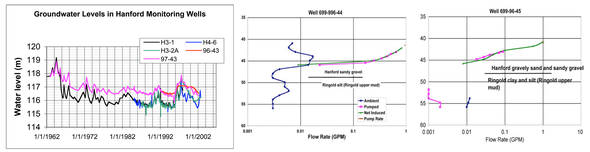


Drilling of Well 699-96-44, May 2003.

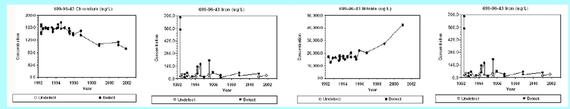
Photographs of cores 4" in diameter



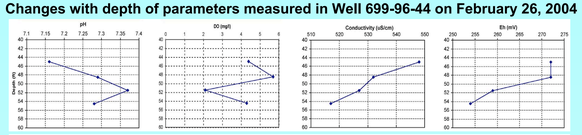
HYDROLOGICAL MEASUREMENTS



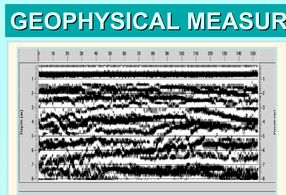
CONCENTRATION MEASUREMENTS (PNNL data)



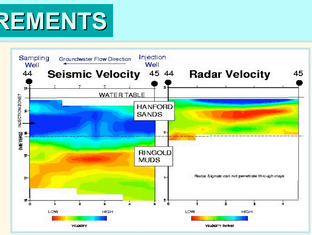
Changes with depth of parameters measured in Well 699-96-44 on February 26, 2004



GEOPHYSICAL MEASUREMENTS

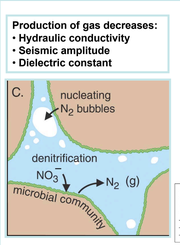


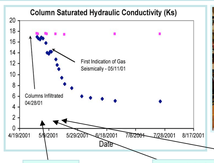
Surface GPR imaging:
- Mapping water table
- Assessing spatial variability
- Delineating hydrostratigraphic units



Seismic and radar tomographic velocity cross-sections between the injection and sampling wells

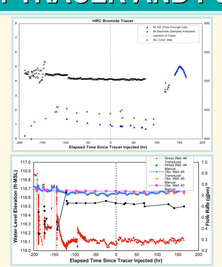
Production of gas decreases:
- Hydraulic conductivity
- Seismic amplitude
- Dielectric constant





Lab experiments show that HRC in the pore space DRAMATICALLY reduces the seismic amplitude relative to that in groundwater

Br TRACER AND PUMPING TEST



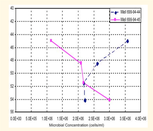
Changes with time of Br concentration and specific conductance.

The tracer was injected at *t*=0 (4/27/2004 11:40 am)

Changes with time of the pumping rate and water levels in the pumping well (699-96-44), and upgradient Wells 699-96-45 (tracer injection well), and 699-96-43.

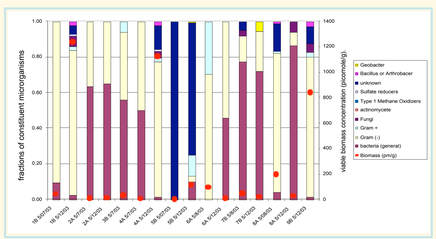
MICROBIAL ANALYSIS

- Terminal restriction fragment length polymorphism (TRFLP) analysis with primers for Fe and sulfate reducers, and nitrate dissimilatory reactions;
- Live/dead direct counts; Phospholipid fatty acid analyses (PLFA), TEA, ED, DOC, DIC, CO_2, O_2 Limiting nutrients, e.g., N, P, S, Fe;
- Nitrogen and oxygen isotope ratio; $^{53}Cr/^{52}Cr$ ratios)



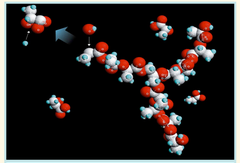
Microbial concentration in groundwater, December 2003

Sample Number	Depth (ft)
1B	37.5-38.0
2A	40.5-41.0
3B	42.0-42.5
4A	43.0-43.5
5B	47.0-47.5
6A	50.0-50.5
7B	52.0-52.5
8A	53.0-53.5
9B	56.5-57.0

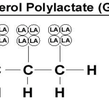


Phospholipid fatty acid (PLFA) analysis of sediments (Well 699-96-45).

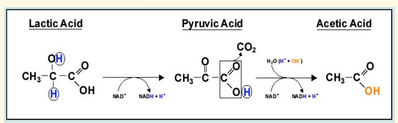
Cr(VI) BIOREMEDIATION USING LACTATE / POLYLACTATE (HRC)



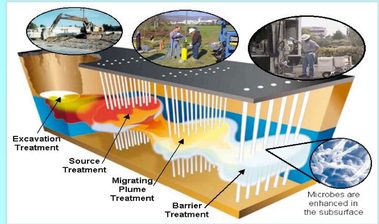
HRC - Glycerol Polylactate (GPL)



HRC properties:
- a polymer of lactic acid (glycerol polylactate)
- slowly releases lactic acid when injected into a aquifer
- Lactic acid or lactate is fermented by indigenous microorganisms to produce H_2, which is a required electron donor
- has a field longevity of 12-18 months
- once injected into the subsurface, slowly releases lactic acid to stimulate anaerobic bacteria and ferment the lactic acid to gain carbon and energy

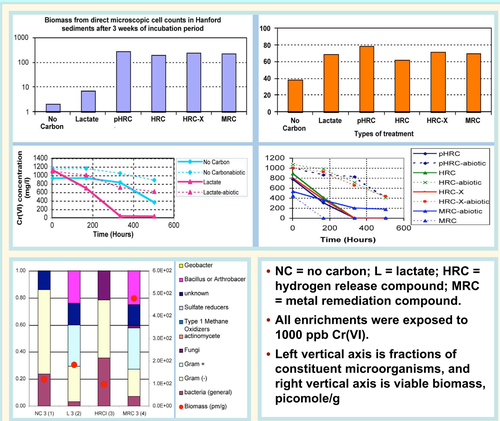


HRC IN GROUNDWATER



- HRC, when injected into chromium contaminated groundwater, will generate electron donors like lactate and hydrogen for microbial production of reducing conditions, which, in turn, stimulate the rapid precipitation of a Cr(III) solids
- Cr(VI) can also be directly reduced to Cr(III) by some bacteria, when HRC is supplied as an electron donor
- HRC also stimulates microbial reduction and production of species that can chemically reduce Cr(VI) to Cr(III) like Fe(II) and hydrogen sulfide.
- The reduction process caused by adding lactate (produced by HRC) and its breakdown products, causes the microbial population to remove the oxygen, nitrate, sulfate and other competing electron acceptors, which, in turn, depresses the redox potential in the aquifer, affecting the transformation of Cr(VI) species to Cr(III) species, which are precipitated on soil particle surfaces.
- Factors affecting Cr(VI) bioremediation are: aquifer geochemistry (inorganic common anions and cations, Eh, pH, temperature and DO), nitrate, oxidation conditions caused by recharge of infiltrating water or water from the river and the presence of manganese oxide.

BENCH-SCALE TESTING OF HRC APPLICATION



- NC = no carbon; L = lactate; HRC = hydrogen release compound; MRC = metal remediation compound.
- All enrichments were exposed to 1000 ppb Cr(VI).
- Left vertical axis is fractions of constituent microorganisms, and right vertical axis is viable biomass, picomole/g

KEY INTERMEDIATE FINDINGS

- Microbial populations ($<10^5$ cells g^{-1}) in the viable soils are probably too low for direct enzymatic Cr(VI) reduction, but after biostimulation increase to more than 10^8 cells/g.
- Several types of bacteria, including *Bacillus/Arthrobacter and Geobacter* species, are present in Hanford sediments, which are known to:
  - withstand high concentrations of heavy metals,
  - metabolize recalcitrant chlorinated compounds, and
  - reduce or sorb hexavalent chromium.
- Because Cr(VI) reduction in sediments is diffusion-rate limited, a small fraction of Cr(VI) in groundwater could remain unreduced and continue moving with the regional flow.
- Cr(VI) bioreduction could occur along with Cr reduction by Fe(II)
- Dissolved oxygen and manganese oxides could cause a small portion of Cr(III) to reoxidize to Cr(VI).
- Cr(VI) can precipitate with Ca in localized zones, decreasing Cr(VI) mobility.
- The natural pH/Eh conditions of an aquifer favor the predominance of Cr(III) under equilibrium conditions
- *In-situ* chemical reduction of Cr(VI) in contaminated groundwater is expected to be a rapid and cost-effective remediation action. Anticipated cost savings are approximately 30-80% over accepted cleanup methods such as pump-and-treat.

ACKNOWLEDGEMENTS

Funded by Joint Natural and Accelerated Bioremediation (NABIR) Program, and the Office of Science and Technology, Office of Environmental Management of DOE

Victor Gruol (LBNL), and Bruce Bjornstad, Darrell Newcomer, and Kirk Cantrell (PNNL) participated in conducting field work.

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